Evaluation of Almaty City Soil's Toxicity by the Representatives of the Microflora and Microfauna

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Abstract − The lowest amount of heavy metals was found outside the city (25 km away), the highest amount was found near the thermoelectric power plant, and the average amount was discovered in the central part of the city. The presence of heavy metals in soil samples resulted in reduction of several important soil characteristics (pH, humus content, soil "breathing"). Use of simple and quick methods to examine soil with high heavy metals pollution resulted in the discovery of a pedobiota group, consisting of nematodes, fungi (genus *Fusarium*) and *Protozoa* which indicated the toxicity of the Almaty city soils.

Key words : heavy metals, soil characteristics, bioindicators, toxic soil

INTRODUCTION

City soils are the urban soils that can accumulate various toxic compounds, causing soil contamination. Heavy metals (HM) are the major soil pollutants characterizing the soil toxicity. HM concentration defines the degree of such toxicity. There has been substantial development of new and modification of existing methods for measuring human impact on the environment. It is considered very important to conduct experimental studies of the biological effect caused by pollutants (Zhygareva *et al.* 2006), and the simple assessment of their concentration could have low value. Soil ecology commonly uses "glass cover growth" method to determine the qualitative and quantitative composition of the soil's microflora and microfauna, and a simple counting of unicellular and multicellular invertebrates, sensitive to the chemical contamination of the soils (Geltzer 1980; Netrusov *et al.* 2005; Zhygareva *et al.* 2006). This is the original research paper, and the purpose of this work is the assessment of toxicity of Almaty city soils contaminated by HM using various bioindicators.

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MATERIALS AND METHODS

City soil samples (5 samples in each site) were collected during 2007～2010 at the following 5 locations in the Almaty city area (Table 1) in accordance with the standardized sampling methodology (General requirements for sampling 1983).

In order to determine the presence of heavy metals, soil samples were subject to atomic absorption spectrometry using the electrothermal atomization equipment AA-6650 produced by spectrophotometer of firm "Shumadzu" (Obukhov and Plekhanova 1991). Number of microbiotic communities was assessed by conventional method of sowing soil suspension on solid nutrient media followed by counting the number of grown colonies (Zvyagintsev 1991). The "glass cover growth" method also known as moist chamber method was used to determine the toxicity of Almaty city soils (Demkina 1989; Netrusov *et al.* 2005). During examination of seasonal dynamics of *Protozoa*, the soil samples were collected in spring and autumn periods in accordance with the standard methodology developed by soil zoology laboratory of the Moscow State University (Gilyarov 1978). The number of nematodes was determined by their extraction from the soil

Table 1. Location of sampling points of the soil samples

Soil sample	Location
No.1	Rayimbek ave. (crossing Pushkin st.), urban soil
No.2	Rayimbek ave. (intersection with Seifullin ave.), urban soil
No.3	Rayimbek ave. (crossing Rozybakiev st.), urban soil
No.4	thermoelectric plant (TEP-1), industry soil
No.5	25 km from the city, control (relatively uncontaminated)

samples and counting (Quantitative methods of soil zoology 1987).

In addition, the following indicators were examined: assessment of pH level using pH meter, quantity of water-soluble humus (Cholodnyi 1935), and soil "breathing" (CO_2 emission) using the special method proposed by Demkina (1989).

Collected data were statistically processed using "Microsoft Excel" and "Statistics 6.0".

RESULTS AND DISCUSSION

3 soil samples' collection points (No.1, 2 and 3) are related to the city central part near heavy traffic roads, and significant amount of soil contamination was associated with proximity to TEP-1 (No.4). Thus, the choice of soil samplings on the territory of Almaty city was based on analysis of the environmental conditions (Ecological Bulletin 2005～2009).

Table 2 presents data on the presence of heavy metals in the studied soil samples. The content, in general, correlates with the degree of human pressure on the environment in these sites: the lowest concentration of HM observed in soil samples taken outside the city, and their highest concentrations-in the sites No.3 and 4, i.e. in the central part of the city at the crossroads of major roads and near the TEP-1.

The concentrations of HM in the first 4 samples ranged 2.2 to 4.8 multiples in comparison with the control sample, but the seasonal differences were not observered. Concentration of Pb was higher in spring, because of the intensive operation of TEP-1 in winter season. Variations of Cu concentration (multiple over the control sample-1.4～2.5 times) did not show a clear seasonality. Zn concentration in soil samples was higher in spring than in autumn.

It is known that a life energy of soil organisms and their cenosis composition is largely dependent on the concentra-

Table 2. The average content of acid-soluble forms of heavy metals (mg kg^{-1}) in Almaty city soil samples

Spring				
Soil sample	Concentration of heavy metals acid-soluble forms, mg kg^{-1}			
	Cd	Pb	Cu	Zn
No.1	0.51±0.02	44.8±3.0	36.4±2.2	59.6±5.8
No.2	0.39±0.05	42.1±2.5	43.7±2.5	59.2±5.2
No.3	0.67±0.07	50.5±3.6	52.7±3.3	59.7±5.4
No.4	0.41±0.04	63.8±4.1	42.8±2.9	60.7±6.1
No.5	0.16±0.02	19.8±1.6	21.5±1.9	41.3±4.2
Autumn				
Soil sample	Concentration of heavy metals acid-soluble forms, mg kg^{-1}			
	Cd	Pb	Cu	Zn
No.1	0.11±0.03	18.7±1.9	22.6±2.1	36.7±5.4
No.2	0.16±0.02	20.4±1.3	22.4±2.2	35.7±3.8
No.3	0.24±0.03	61.4±4.2	36.2±3.5	57.2±3.9
No.4	0.17±0.02	41.6±3.7	33.5±2.3	49.6±4.5
No.5	0.05±0.03	15.8±1.7	16.3±2.3	28.4±2.2

Table 3. Changes of chemical and biological parameters of soil samples

Spring			
Soil sample	pH	Humus, %	Mmol CO_2 g^{-1} hour^{-1}
No.1	8.34±1.1	2.3±0.47	1.13±0.02
No.2	8.92±0.9	1.6±0.32	1.18±0.09
No.3	8.75±0.8	1.0±0.23	1.20±0.03
No.4	8.49±1.2	1.3±0.26	1.08±0.03
No.5	7.01±1.0	3.0±0.65	1.16±0.03
Autumn			
Soil sample	pH	Humus, %	Mmol CO_2 g^{-1} hour^{-1}
No.1	7.96±1.5	3.4±0.67	1.14±0.02
No.2	8.43±1.2	2.7±0.52	1.30±0.02
No.3	8.71±0.6	2.2±0.42	1.19±0.06
No.4	8.77±1.6	2.3±0.47	1.15±0.04
No.5	7.12±1.3	4.2±0.85	1.14±0.03

tion of H^+ ion. We discovered that Almaty city soils had a pH reaction close to alkaline, only the control samples had a neutral pH reaction, i.e. can be concluded that soil with a minimal HM contamination had a neutral pH reaction, whereas heavily contaminated urban soils had alkali and alkaline reactions (Table 3). The highest alkaline was found in soil samples taken in the vicinity of TEP-1 highly contaminated with Pb.

Lack of residues on the soil surface facilitates treatment of humus and nutrient content, leaf litter is quickly hydrolyzed in organic compounds (carbohydrates, amino acids, organic acids) enriching the soil with water-soluble humus. Arti-

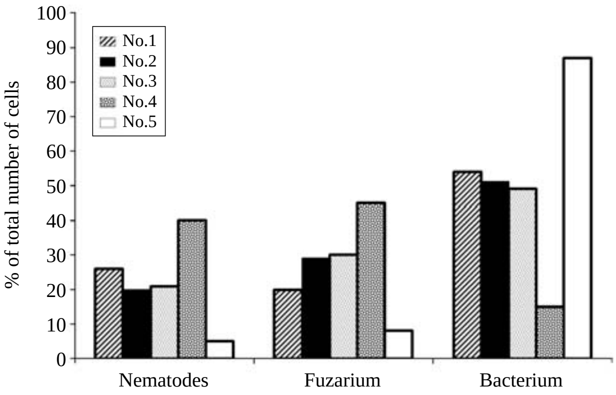

Fig. 1. Pedobiota's content in soil samples (%).

Table 4. Comparison of *Protozoa* quantity ($\times 10^3$ cells g^{-1}) in soil samples

Object	Control	Urban soils
Spring		
Ciliates	6.8 ± 1.22	4.0 ± 1.1
Flagellates	71.5 ± 3.6	55.1 ± 3.1
Naked amoebae	24.0 ± 2.3	20.5 ± 2.03
Autumn		
Object	Control	Urban soils
Ciliates	15.6 ± 1.5	12.2 ± 1.6
Flagellates	137.5 ± 5.2	119.3 ± 6.8
Naked amoebae	13.8 ± 1.7	11.8 ± 1.4

ficial removal of leaf litter and various anthropogenic factors leads to a decrease of humus' content in urban soils.

The humus content was highest in all of the spring samples and in the autumn control site soil samples (No.5), slightly lower in site No.1, and the lowest concentration in the samples from site No.3 (2.3 times less than in the control soil samples). Soil samples from sites No.2 and 4 also had lower humus concentrations than the control one both in the spring and in autumn samples (Table 3). Therefore, low humus content reported for urban soils, and its content in the control site correspond to the typical steppe light chestnut soils.

Humus concentration in the autumn soil samples was higher than in spring, its maximum concentration was recorded in the control soil samples (No.5); in urban soils its content was approximately 2 times lower. Thus, urban soils in spring and in autumn had low humus content.

One of the important indicators of soil biological activity is its "breathing" intensity since CO_2 as an end product of the organic decomposition reflects of the level of the soil microflora's activity and the activity of other biological processes in soil. The mean values of CO_2 emission in the spring were low in all Almaty's soil samples, collected in the urban sites near heavy traffic roads. It is possible that in early spring, the soil had not reached the optimal parameters, including "breathing", but we noted the increased emission CO_2 in the urban soils compared with control sample (Table 3).

In general, the intensity of CO_2 emission in urban and control soil samples was higher in the autumn period.

"Glass cover growth" method revealed that communities of organisms from site No.4 (TEP-1) consisted of nematodes (40%), microscopic fungi (genus *Fusarium*-45%), which are among the most dangerous fungi that cause plant diseases. And common bacteria-15% (Fig. 1). These data characterize the analyzed soil sample as very toxic to plants.

In soil samples taken from the conventionally uncontaminated soil (No.5) a different picture was observed: fungi and nematodes in small amounts (about 5 and 8% respectively), and much more of bacterial colonies. From the soil samples taken in the city center near major highways, the qualitative composition of microcenosis was as follows: *Nematodes* and *Fusarium* accounted for about 45%, bacteria accounted for the remaining 55%, i.e. in those samples with medium concentrations of HM, we also found dangerous or phytotoxic organisms, but their quantity is almost equal to the number of bacterial colonies that signaled the average level of toxicity in these soil samples. Use of simple and quick methods using the number of *Nematodes* and fungi *Fusarium* as an indicator allowed us to identify soils with the maximum concentration of HM.

In Table 4 are presented average data on the quantitative and qualitative composition of the microfauna in the studied soil samples. In autumn the number of ciliates and flagellates in all soil samples was higher 2.3 and 1.9 times respectively than in spring samples, the number of naked amoebae was lower 1.7 times. We assume that it was due to the seasonal soil conditions, particularly, to higher soil moisture.

In the control soil samples (not contaminated with HM) flagellates were the dominant group both in spring and in autumn (69.9 and 82.4% respectively) and naked amoebae in spring (14.3%); subdominant was ciliates both in spring and in autumn (6.7 and 9.4% respectively), and naked amoebae in autumn (8.3%). In urban soils the absolute dominant regardless of the season was flagellates (69.2% of the total number *Protozoa* in spring and 83.3% in autumn); abundance of naked amoebae (25.8%) in urban soils during spring has also allowed to include them to dominants. The number of naked amoebae was lower in autumn samples, and the number of ciliates was little influenced by seasonality. Naked amoebae in autumn period (8.2%) and ciliates (5% in spring and 8.5% in autumn) were attributed to the subdominant.

In both spring and autumn periods, Cd had a strong inhibitory effect on naked amoebae and Pb showed a slightly less of an inhibitory effect; Cu had stronger toxic effect on naked amoebae in autumn than spring; Zn had the weakest inhibitory effect that was also smaller in autumn than in spring. Ranking of HM toxicity in autumn samples for naked amoebae was the same as for spring: Cd > Pb > Cu > Zn.

CONCLUSIONS

1. The lowest HM content was observed in soil samples taken outside the city, and the highest in the city central part at the crossroads of major highways and near the TEP-1.
2. Control samples had a neutral pH, and urban soils showed alkali and alkaline values.
3. The highest content of water-soluble humus was in the control sample taken outside the city, the lowest in urban and industry soils.
4. The "breathing" of urban soil samples was less 1.1～1.3 times compared with the control samples.
5. Identified composition of soil samples' microcenoses: (a) contaminated soils: 40% nematodes, 45% *Fusarium*, 5～8% nematodes and fungi; (b) uncontaminated soil: about 85% bacteria.
6. Abundance of naked amoebae declined significantly in autumn by the toxic effect of Cd and Pb; Cu inhibited the number of amoebae equally in spring and in autumn; Zn inhibition effect was higher in spring.

Thus, the presence HMs in the urban soil led to a decrease of some soil cenosis characteristics (pH, humus content, soil "breathing"). Qualitative and quantitative composition of Almaty city soil microcenosis had changed, which contained both a large number of nematodes and *Fusarium*, and naked amoebae that reflected phytotoxic properties of the soils. General conclusion: state of Almaty city's soil cover causes serious concern, because of high concentrations of HM identified in the upper soil horizons in various sites, and many of the soil ecological indicators are influenced by the toxic effect of HM contamination.

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